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FEDERAL PHOTOVOLTAIC UTILIZATION PROGRAM

FINAL REPORT

OF THE

ENVIRONMENTAL PROTECTION AGENCY

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MASTER

PREPARED BY:

DAVID R. BERG

OFFICE OF RESEARCH AND DEVELOPMENT

AND

JEFFREY VAN EE

OFFICE OF RESEARCH AND DEVELOPMENT

JON BROADWAY

OFFICE OF RADIATION PROGRAMS

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FEDERAL PHOTOVOLTAIC UTILIZATION PROGRAM: FINAL REPORT OF THE ENVIRONMENTAL PROTECTION AGENCY

Introduction and Summary

EPA has completed its activities on the Federal Photovoltáic Utilization Program (FPUP), funded through interagency agreement EPA-80-R-X0780 (DOE #DE-AI01-79CS30085) on a cost reimburseable basis. The overall goal of the FPUP is to further the commercial use of photovoltaic systems within the Federal and commerical sectors and a secondary goal has been to promote market development by "utilizing the vehicle of large-scale procurement." Under FPUP, EPA conducted 12 projects, building 39 separate photovoltaic power systems. A thirteenth project originally awarded by DOE* was cancelled because EPA's power requirements changed. All projects funded by the interagency agreement to design, construct, and operate photovoltaics have been completed, except as previously agreed by DOE or its systems contractor, and all photovoltaic systems are currently in use at their original site or other sites, or remain useable.

The EPA experience with photovoltaics applications funded through FPUP has been satisfactory. Solar power systems proved to be clean, dependable, and quiet electricity sources in remote areas. Previously, such sources were expensive or even unavailable. Several pioneering efforts were completed under EPA FPUP projects. Most notably, perhaps, the National Park Service is

* Number 00933 (Mobile Radiation Monitor Lab) for $45,046.

using replicates of EPA's solar-powered visibility monitoring stations throughout the National Park System. One of the FPUP systems powers a remote monitoring station near a nuclear power plant, while others have been used to monitor air quality during the cleanup of contaminated waste sites. This final report contains short summaries of the status and funding of each of EPA's FPUP projects; a list of the projects awarded to EPA (Appendix 1); and longer descriptions of EPA's FPUP projects (Appendix 2).

At this time, EPA does not plan to design, install, or operate additional photovoltaic power systems for environmental projects. Previously, plans existed to deploy national monitoring networks for such environmental concerns as visibility and noise, but Agency priorities have changed. On the other hand, the existing photovoltaic power systems are being retained by EPA or made available to other agencies, such as the National Part Service, and have found use in a number of unanticipated situations. EPA is preparing a technology transfer report for distribution to all EPA offices and to other environmental agencies that will describe cost-effective environmental monitoring applications for photovoltaic power systems. In addition, the EPA technical staff who have guided EPA's involvement in FPUP projects will continue to provide to the Agency an in-house photovoltaic capability.

Fiscal and Technical Management

EPA received $1,224,079 from the Department of Energy in the three cycles of FPUP, of which $45,046 was returned for a cancelled project. The final $4,150.89 will be expended to prepare a technology transfer document on the best applications of photovoltaics to remote environmental

monitoring. Within EPA, the Office of Research and Development (ORD) is the FPUP lead office. Two of EPA's major offices (ORD and OAR, the Office of Air and Radiation) and EPA Region VIII were awarded FPUP projects. (The Region VIII projects were carried out by ORD.) Project responsibility was delegated to the Environmental Monitoring Systems Laboratory in Las Vegas (EMSL-LV) and the Eastern Environmental Radiation Facility (EERF) of OAR.

David Berg has served as EPA Program Director for the life of the interagency agreement under the general direction of the Assistant Administrator for Research and Development. Jeff van Ee and Dr. Jon Broadway performed as FPUP technical monitors at EMSL-LV and EERF, respectively.

Of the twelve EPA projects, EMSL-LV had responsibility for nine: five projects in Cycle I ($258,357.00), four projects in Cycle II ($159,929.00), and no projects in Cycle III. These projects were:

ID Number	Project Title	Total Funds
00936	Airport Noise -- Longmont	$ 38,799
00934	Grand Teton Noise Monitor	25,143
00924	Monitoring Instrument Pack 4	30,116
00928	Visibility Measurements	156,784
00932	Visibility Monitoring Site	7,515
02608	Hi-Vol Particulate Sampler	26,691
02607	Hi-Vol Particulate Sampler	26,120
02594	Mobile SO_2 Sampler	20,881
02574	Particulate Samplers	86,237
	Total	$ 418,286

The EERF had responsibility for three projects: one in Cycle I, one in Cycle II, and one in Cycle III. These projects were:

ID Number	Project Title	Total Funds
00918	Western Region Radiation Samplers	$ 270,276
00912	Eastern Region Radiation Samplers	356,136
07027	Nuclear Power Plant Peripheral Monitoring Station	,134,300
	Total	$ 760,712

All resources assigned to the EMSL-LV and EERF have been spent and a majority of the monies were subcontracted to the principal on-site systems contractor in Las Vegas -- Lockheed Engineering Management and Support Company (Lockheed EMSCO) -- and to the principal systems contractors in Alabama -- Auburn University/Montgomery and Vachon Nix Associates of Atlanta, GA. These contractors were assigned specific responsibilities by the EPA technical monitors to:

- Purchase photovoltaic components
- Design photovoltaic electrical systems and mechanical structures
- Fabricate photovoltaic power systems and integrate them with electrical loads
- Deploy the photovoltaic systems
- Maintain the systems over a limited period of time until they were proven to be dependable and could be maintained by others
- Monitor the performance of the photovoltaic systems.

Other contractors were used by the EPA either through small contracts

with Lockheed EMSCO or directly through contracts with the EPA-Montgomery facility. Some efforts were made by EPA to utilize FPUP funds directly to purchase components and agency personnel designed, fabricated, and deployed photovoltaic components and systems. At the start of FPUP, emphasis was placed on saving money through the combined purchase of photovoltaic components between EMSL-LV and EERF. (Purchased components were utilized in a number of DOE-sponsored projects that were constructed by the EPA and its contractors.) The large number of FPUP projects and the limited number of agency personnel available to work on FPUP quickly led, however, to the contracting out of a major portion of EPA's FPUP effort.

From the original evaluation and selection of photovoltaic applications by DOE to the installation of photovoltaic systems in the field by EPA, numerous changes occurred in program administration and personnel, and in the purpose, location, and final power requirements for some DOE-approved photovoltaic applications. EPA adhered to the FPUP guidelines in making these changes, while meeting both the EPA objective of powering environmental instrumentation in remote areas with photovoltaics and the DOE objective of promoting the development and use of photovoltaics. DOE and the Jet Propulsion Laboratory (JPL) requested periodic updates on the FPUP program as administered by EPA, and changes in the program were agreed to by responsible officials at EPA, DOE and/or JPL on an individual basis. The periodic JPL reviews and progress updates were a feature of EPA's program.

Project Descriptions

The projects originally approved and funded by DOE for EPA are listed in Appendix 1. Short descriptions of how those projects were eventually

implemented follow. Detailed accounting of the expenses attributable to the projects completed by EPA vis-a-vis the projects originally approved by DOE is not given because the consolidated buys of components and the general overhead expenses of contractors cannot be broken down readily to the individual project level. The flow of resources was made more complex, moreover, because numerous approved changes occurred between the original selection of projects by DOE and the final design, construction, and deployment of systems by EPA.

Following are short descriptions of the projects completed by EPA (correlated with the projects approved originally by DOE). Longer descriptions are provided in Appendix 2:

° Projects 00934 and 00936 (noise monitoring in Colorado) were eliminated, and the funds were applied to the construction of one, 720 watt (peak) photovoltaic trailer for environmental measurements in remote areas and several small photovoltaic systems that were deployed in the Colorado-Utah region. A prototype visibility monitoring station was installed in the Flattops Wilderness Area in Colorado. Other small photovoltaic systems were installed at Vernal, Utah, and in the Dinosaur National Park. Additional photovoltaic components were transferred to the National Park Service to power an acid rain monitoring station near Boulder, Colorado.

° Project 00924 was built as originally planned to provide the photovoltaic systems that power radiation monitors around the Nevada Test Site.

° Project 00928 authorized the construction of EPA's first large-scale use of photovoltaics at Zion National Park and three other National Parks.

The Zion power and visibility monitoring systems were built as originally planned. The requirements for EPA's visibility monitoring program then changed and the three remaining large-scale power systems were not built. Instead, the monies were used to buy components and to construct six small-scale systems that were given to the National Park Service for its visibility monitoring program. Deployment at additional sites is pending. Changes in the visibility monitoring effort in Zion National Park led to the transfer of the 1.4 kw (peak) photovoltaic system to the National Park Service. This unit will now be used at another site in the Park by the Service. The visibility monitoring station at Lava Point was reconfigured and powered by a small-scale photovoltaic system authorized in 00932.

° The "Hi-Vol particulate sampler" authorized in project 02608 was built as proposed, but was deployed in Fort Duchesne, Utah, rather than in Colorado.

° The photovoltaic system required for the "Hi-Vol particulate sampler" authorized in project 02607 was used to power an ozone measurement instrument in a remote area of Sequoia National Park.

° The "mobile SO_2 sampler" under project 02594 was constructed as originally conceived.

° The 20 "particulate samplers" designated under project 02574 were constructed as originally conceived. The units are being used to power a variety of battery-operated environmental instrumentation and the units have gained recognition as "Solar Backpack Power Sources."

° Units of 3 different sizes designed to power environmental monitoring equipment in remote locations were constructed under project 00918: two, 720 watt (peak) mobile units mounted on dual axle trailers; four, 320 watt (peak) single-axle trailer mobile units; and one, 4000 watt (peak) stationary unit. These units have been used for a variety of purposes at monitoring sites, including river sampling and air quality sampling in the Great Smokey Mountain National Park. The stationary unit has been in continual operation since 1982 at the Farley Nuclear Plant in Alabama.

° Resources from Project 00912 supported the construction of units of three different output capacities. These were one, 720 watt (peak) trailer-mounted unit; four, 800 watt (peak) units mounted on trailers; and one, 4000 watt (peak) modular fixed unit that can be assembled to provide differing power requirements. Mobile units constructed under Project 00912 have been used to power air samplers during the cleanup of the Weldon Spring Chemical Plant in Missouri.

° One, 6000 watt (peak) photovoltaic power supply for an environmental monitoring station was designed and built using an advanced design under Project 07027. This unit is in operation at a stationary radiation monitoring site in Montgomery and powers a variety of environmental monitoring equipment. Replicates may be used in remote areas.

APPENDIX 1

FEDERAL PHOTOVOLTAIC UTILIZATION PROGRAM: FINAL REPORT OF THE ENVIRONMENTAL PROTECTION AGENCY

FEDERAL PHOTOVOLTAIC UTILIZATION PROGRAM

PROJECTS ADMINISTERED BY THE ENVIRONMENTAL PROTECTION AGENCY

ID NUMBER	ORIGINAL PROJECT TITLE		FUNDS TRANSFERRED
Cycle I			
00936	Airport Noise - Longmont		$ 38,799
00934	Grand Teton Noise Monitor		25,143
00933	Mobile Radiation Monitor Lab		45,046
00924	Monitoring Instrument Pack 4		30,116
00928	Visibility Measurements		156,784
00932	Visibility Monitoring Site		7,515
00918	Western Region - Radiation Sampler		270,276
		Total	$ 573,679
CYCLE II			
00912	Eastern Region - Radiation Sampler		356,136
02608	Hi-Vol Particulate Sampler		26,691
02607	Hi-Vol Particulate Sampler		26,120
02594	Mobile SO_2 Sampler		20,881
02574	Particulate Samplers		86,237
		Total	516,065
CYCLE III			
7027	Nuclear Power Plant Peripheral Monitoring Stations -- EPA		134,300
		Total	134,300
AGENCY TOTAL:	ALL PROJECTS		1,224,044

APPENDIX 2

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Projects 00928 and 00932

LARGE-SCALE AND SMALL-SCALE PHOTOVOLTAIC SYSTEMS FOR ZION NATIONAL PARK

The Environmental Protection Agency's (EPA's) first large-scale use of photovoltaic energy powered a 250 watt visibility monitoring system at Lava Point in Zion National Park (Project 00928). The system was installed by the Environmental Monitoring Systems Laboratory in Las Vegas (EMSL-LV) during the summer of 1980 and provided power until the summer of 1982, when the visibility monitoring system was replaced with smaller, 6-watt monitoring equipment that requires an approximately 120 watt (peak) photovoltaic power supply (Project 00932). The original 1.4 kW (peak) photovoltaic system was transferred to the National Park System and will be moved by the Park Service to a nearby summer ranger's residence where the power will be used for domestic electricity. Future applications of large-scale systems to power visibility monitoring equipment in wilderness or park environments are not expected since low-power monitoring systems have been developed which utilize smaller power systems. These low-power photovoltaic visibility monitoring systems are being used widely by the National Park Service.

Projects 02594, 00934, and 00936

720 WATT (peak) MOBILE PHOTOVOLTAIC SYSTEMS FOR AIR QUALITY MONITORING

Two trailer-based systems were constructed by the Environmental Monitoring Systems Laboratory-Las Vegas (EMSL-LV) to power ozone or sulfur dioxide instruments. The trailers were built jointly with EPA's Eastern Environmental Radiation Facility (EERF) and utilize high-density photovoltaic panels and a 1000 amp-hour nickel-cadmium battery bank. (A more complete description of the system is given in EPA's "Solar Power Systems for Environmental Monitoring", December, 1981). The trailers at EMSL-LV are available for use on a first-come-first-served basis, but have not been used for extended periods in the field.

Project 02574

SOLAR BACKPACK POWER SOURCES

Twenty portable photovoltaic systems were developed that utilize 40-watt, high-density solar panels and high energy density nickel-cadmium batteries. (A more complete description of the system is given in EPA's document "Solar Power Systems for Environmental Monitoring", December, 1981.) The systems have been and continue to be used to monitor air quality in remote areas. Units have been backpacked into isolated areas of the Olympic National Park, Hawaii Volcanoes National Park, New Hampshire, and Nepal. Backpack units are also being used by the EPA to measure ionizing radiation in the vicinity of the Nevada Test Site. Continued usage of the units by the EPA and the National Park Service is anticipated in the future. Some private sector interest has been expressed about the units, but to date concrete industry plans to fabricate additional units have not emerged.

Projects 00934, 00936, and 00928

SMALL, MODULAR PHOTOVOLTAIC SYSTEMS FOR MONITORING VISIBILITY IN THE WEST

A prototype visibility monitoring system which utilizes photovoltaics and satellite telemetry was designed and installed by the EMSL-LV in the Flattop Wilderness in Colorado. (A more complete description of the system is covered in EPA's "Solar Power Systems for Environmental Monitoring," December, 1981.) The system utilizes three, 40 watt high-density photovoltaic panels and small nickel-cadmium batteries. The system operated successfully over one season before it was removed due to a change in the requirements of the visibility monitoring program. The system at Flattop served as the model for six small-scale visibility systems that were built and transferred to the National Park Service where they are operating today in six western parks, including the Grand Canyon National Park and Bryce Canyon National Park. Four similar systems are being built by EMSL-LV, and they will be deployed and operated in four National Parks by EPA in the summer of 1985 as part of a nationwide visibility monitoring network.

Project 02607

MODULAR PHOTOVOLTAIC SYSTEM FOR MONITORING OZONE IN SEQUOIA NATIONAL PARK

A 540 watt (peak) system was developed by the EMSL-LV to power a modified, commercially-available ozone monitor. The system is presently operated in Sequoia National Park by the National Park Service. Ozone and photovoltaic performance data is relayed from the remote area of the Park to the California Air Resource Board's offices in Sacramento for analysis. The joint development and operation of the ozone monitoring system by the EPA, California Air Resources Board, the National Park Service, and DOE has effectively demonstrated that ozone damage to trees can be monitored using photovoltaic-powered instrumentation. The use of additional solar-powered ozone instruments by air quality and natural resource agencies is anticipated as more people learn of the successful operation of the system in Sequoia National Park.

Project 02608

SOLAR POWERED HI-VOL SAMPLER

The Ute Indian Reservation at Fort Duchesne, Utah, is utilizing a solar powered high-volume (hi-vol) air sampler for the collection of particulates. Air quality degradation associated with energy development in this isolated region will be assessed with this photovoltaic system and the particulate sampler. The unit was originally placed in the Colorado National Monument, but the site proved unsuitable for a photovoltaic system. The system was moved and extensive testing confirmed that the photovoltaic-powered hi-vol samplers meet the specifications established for conventional hi-vol samplers. The 480 watt (peak) system is operating today under the direction of the Ute Indians. Further applications for solar powered hi-vol samplers are anticipated, but no plans are considered definite at present.

Project 00924

THREE 40 WATT (peak) PHOTOVOLTAIC SYSTEMS FOR MONITORING RADIATION NEAR THE NEVADA TEST SITE

EMSL-LV integrated a 40 watt high-density solar panel with a commercial monitoring instrument to measure radiation in the environment. Three systems were developed and installed on a permanent basis around the Nevada Test Site. The systems remain in operation and no major problems have been experienced since they were deployed. Systems similar to the three designed and built by EMSL-LV may be cost-effective for monitoring radiation at sites along the fence line around nuclear reactors where electrical power is unavailable. Other than a larger one built by EPA in Alabama, however, no plans to utilize this photovoltaic application are known.

Projects 00934 and 00936

SMALL-SCALE PHOTOVOLTAIC SYSTEMS FOR MONITORING ENVIRONMENTAL QUALITY IN EASTERN UTAH AND WESTERN COLORADO

Two, 40 watt high-density solar panels were installed by the National Park Service to power a visibility monitoring station in Dinosaur National Park. The Dinosaur site uses photovoltaic panels and environmental instrumentation provided by EMSL-LV.

One, 40 watt high-density panel was used to power an EPA satellite-telemetry system and meteorological instrumentation at a Department of Energy tar sands development site. This equipment, deployed at Vernal, Utah, worked reliably for approximately one year. Monitoring at the tar sands site was then terminated and the systems were removed.

Project 00918

ENVIRONMENTAL MONITORING POWER SYSTEMS

Photovoltaic power supplies for environmental monitoring units with three different power requirements were constructed by the Eastern Environmental Radiation Facility (EERF) in Montgomery, AL. These were: two, 720 watt (peak) mobile units mounted on dual axle trailers; four, 320 watt (peak) mobile units mounted on single-axle trailers; and one, 4000 watt (peak) stationary unit. Each of the units was designed to power environmental monitoring equipment in remote locations and equipped with battery capacity to provide continuous operation for 5 to 6 days without sunlight.

Operational Experience

Each of these units has been tested and utilized in the field since being constructed. Only one equipment failure occurred in these units, that being the failure of an ABACUS inverter almost immediately upon system startup. This inverter was repaired under warranty and has performed satisfactorily since that time. All other components -- panels, batteries, controllers, and transport units -- have performed without failure. Quantitative system performance has been documented during an acceptance test plan and each unit has performed in accordance with its design criteria. In general, overall system efficiencies have ranged 6-8% of solar energy collected. Each unit has been found satisfactory for the purpose intended. One of the 320 watt (peak) trailer units has been powering a remote water sampling station on the Chattahoochie River since 1982 without any problem.

Notable Features and Achievements

All trailer mounted units employ gas springs to assist in raising and lowering the photovoltaic sub-arrays. Users have found this feature to be attractive in that one person can assemble and disassemble the units without assistance. All trailer units employ nickel-cadmium batteries which have been found sufficiently rugged for this application. The fixed unit (4000 watts/peak) operates an environmental monitoring station in a remote area south of the Farley Nuclear Plant near Ashford, AL.

One of the 720 watt (peak) units was displayed at the 15th IEEE Photovoltaic Specialists Conference in Orlando, Florida, in May 1981. Considerable interest in the unit was expressed by conference attendees from several countries.

Future Applications

One disappointment regarding these units is that few organizations have been sufficiently interested in present applications of remote photovoltaic power to consider constructing additional units with their own funds. Cost remains a major obstacle to wider application in the domestic market. Two areas in which applications appear promising are the international (where the economics are more attractive) and military markets (which cannot rely on conventional, grid-based electricity).

Cost Accounting Summary

	Units	Unit Size	Total Peak Watts	$/Wp
	4	320 Wp	1280	
	2	720 Wp	1440	
	1	4000 Wp	4000	
Total	7		6720	$38.04

Project 00912

POWER SYSTEMS FOR ENVIRONMENTAL MONITORING STATIONS

Units of three different output capacities were constructed by the EERF. These were one, 720 watt (peak) unit that is essentially identical with those constructed under Project 918; four, 800 watt (peak) units that are mounted on trailers, use higher efficiency Arco M-53 modules rated at 44 watts output, and are otherwise similar to the 720 watt (peak) unit; and one, 4000 watt (peak) modular fixed unit that can be assembled to provide battery storage for 5-6 days without sunlight.

Operational Experience

Each of these units has performed without equipment failure since construction. System performance as measured during an acceptance test has been consistent with design criteria. The units have been used to power environmental monitoring equipment in a variety of environments, including the Weldon Spring Chemical Plant in Missouri and the Great Smokey Mountain National Park.

Notable Features and Achievements

All trailer-mounted units employ gas springs as sub-assemblies and nickel-cadmium batteries as described under Project 00918. One of the units has been loaned to Oak Ridge National Laboratory for use in precision air quality monitoring in the Great Smokey Mountain National Park. The photovoltaic power source is a unique advantage in this application because exhaust contamination from a fuel-powered generator would affect the GC-MS monitoring equipment being used to study trace atmospheric impurities. Three of these units have also been used for a period of nine months during the hazardous materials cleanup of the Weldon Spring Chemical Plant in Missouri. One of the modular units has powered a water sampling station in eastern Alabama since 1983.

Future Applications

There are no present plans to construct further units using internal program funds. Cost continues to be a major obstacle.

Project 00912 (continued)

Cost Accounting Summary

Units	Unit Size	Peak Watts	$/Wp
1	720 Wp	720	
4	800 Wp	3200	
1	4000 Wp	4000	
6		7920	$44.97

Project 07027

LARGE FIXED-SITE ENVIRONMENTAL MONITORING STATION

One, 6000 watt (peak) power supply for an environmental monitoring station was constructed for the EERF. The unit has many features in common with the 4000 watt (peak) unit constructed under Project 00918, but employs Solarex polycrystalline panels instead of single crystal silicon. The unit also employs the Solarex ACR-6 system controller to optimize battery capacity by using a saw-tooth pulse charger. The unit uses 60-C&D lead calcium cells that each have 350 amps hour capacity and can together store 5 to 6 days of energy requirements.

Operational Experience

The unit has been operational for over a year at this writing and has performed satisfactorily. The design load is a continuous requirement for 600 watts of power at 120 volts AC.

Notable Features and Achievements

Costs for this unit were roughly half of the average system costs of previous projects conducted by EERF when calculated on a "per peak watt" basis. This lower system cost is attributable to the experience gained from the earlier projects. The system cost of $21.72 per peak watt for this project should be indicative of the cost for similar systems constructed in the near future.

Future Applications

This unit is of a size and cost which should be very attractive for a wide range of remote applications, particularly in countries without existing electrical distribution and in remote locations in the U.S. at which continuous power supplies are needed. Applications where similar units may be appropriate include telecommunications relay stations, water pumping, and residential or commercial refrigeration in remote areas.

Cost Summary Table

Unit Size	Peak Watts Produced	$/Wp
6000 Wp	6000	$21.72